THREE-DIMENSIONAL LIGHTNING MAPPING OBSERVATIONS OF SUPERCELL STORMS

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I. INTRODUCTION

Several supercell storms have occurred within the region in which the Oklahoma Lightning Mapping Array (OKLMA) maps all three spatial dimensions of lightning. These storms span much of the supercell spectrum -- from non-tornadic storms to storms that produced strong tornadoes and from low-precipitation to heavy-precipitation morphologies.

II. LIGHTNING OBSERVATIONS

As noted by several studies (e.g., Krehbiel et al. 2000, MacGorman et al. 2005), lightning density maps of supercell storms often exhibit features similar to those seen in radar reflectivity, including lightning rings (often called lightning holes) over the bounded weak echo region (Fig. 1) and V-structures near storm top. Supercell storms also tend to have much larger flash rates than ordinary isolated thunderstorms; maximum rates are typically hundreds of flashes per minute, even when considering only flashes that produce at least ten mapped points per flash (e.g., Williams et al. 1999, Weins et al. 2005, MacGorman et al. 2008).

However, the OKLMA indicates that the many flashes occurring near the updraft during periods of high flash rates tend to have quite small spatial extents, many with a long dimension of 5 km or less. Not usually included in these flash rates are a large number of mapped points that appear to be isolated (sometimes called singletons), each failing criteria of distance or time for associating it with other points in a flash.

Often determining whether these isolated points are artifacts of the OKLMA is difficult, but in the overshooting top, they present a coherent pattern that appears plausible (Fig. 2). They cluster in a cap higher than other lightning in the storm and have horizontal dimensions comparable to that of the overshooting top. They occur continually, but are too far apart in time or space to be associated with each other as part of a flash. A comparison with high-resolution reflectivity data for one storm shows that these isolated points were most concentrated near the top of the 30-40 dBZ echo in the overshooting turret, but some occurred higher, extending up to regions of small reflectivity (roughly 15 dBZ) in the overshooting top (Fig. 3). These points may be similar to the continual lightning noted by Bill Taylor in the upper region of a severe storm in the early 1980s. They also may be related to the small hairs of light which Walt Lyons observed extending through the surface of an overshooting top in optical images, a phenomenon which he called gnomes.

Lightning in many supercell storms extends a few tens of kilometers into the anvil. However, in a few supercell storms lightning is initiated in the anvil 40-100 km from the nearest 35 dBZ radar reflectivity contour. These initiations have been observed in a few situations: (1) when the shallower anvil of a nearby left-moving storm merges with the anvil of a right-moving storm (Fig. 4), (2) when precipitation appears to grow in the anvil and produces downward tendrils of reflectivity, and (3) when the anvil includes weak convective cells.

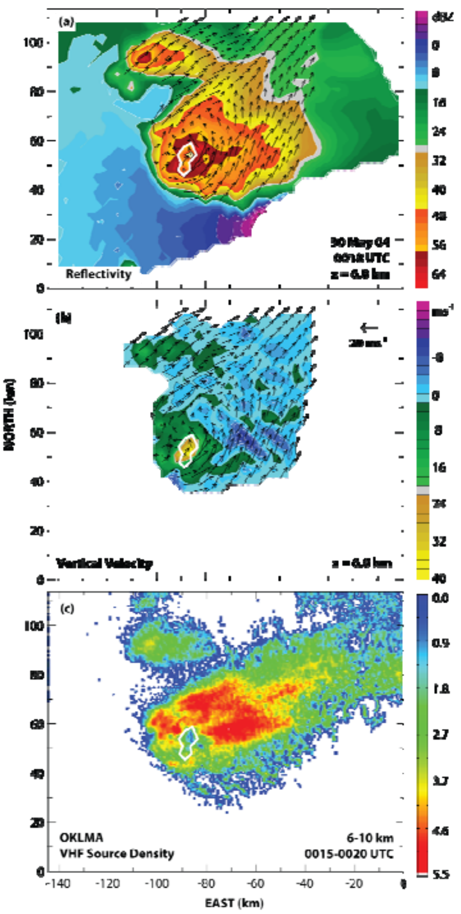

FIG. 1: Dual Doppler radar reflectivity and horizontal winds (upper), vertical velocity (middle), and natural log of VHF source density (bottom) (from MacGorman et al. 2008). The white contour shows the bounded weak echo region.

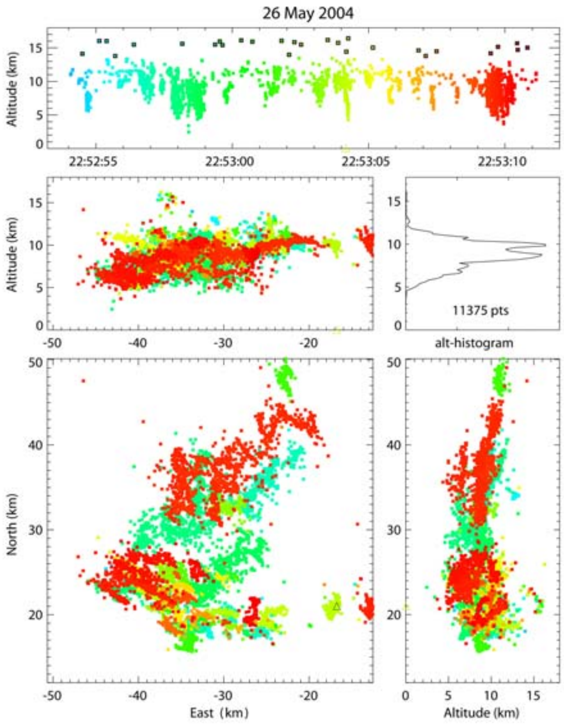

FIG: 2. Mapped VHF sources from 2252:50 to 2253:15 UTC on 26 May 2004. Color indicates the progression of time indicated in the top panel.

III. AKNOWLEDGMENTS

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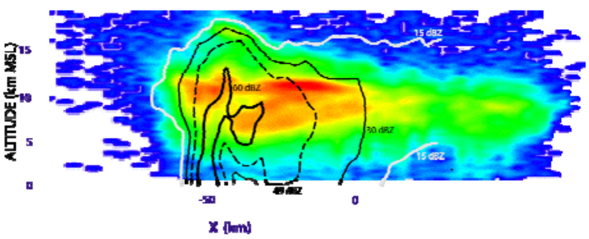

FIG. 3: Lightning VHF source density (natural log scale indicated by color shading) versus radar reflectivity (contours) for the 29-30 May 2004 supercell storm. Note the lightning extending upward into the overshooting turret and extending downshear into the anvil.

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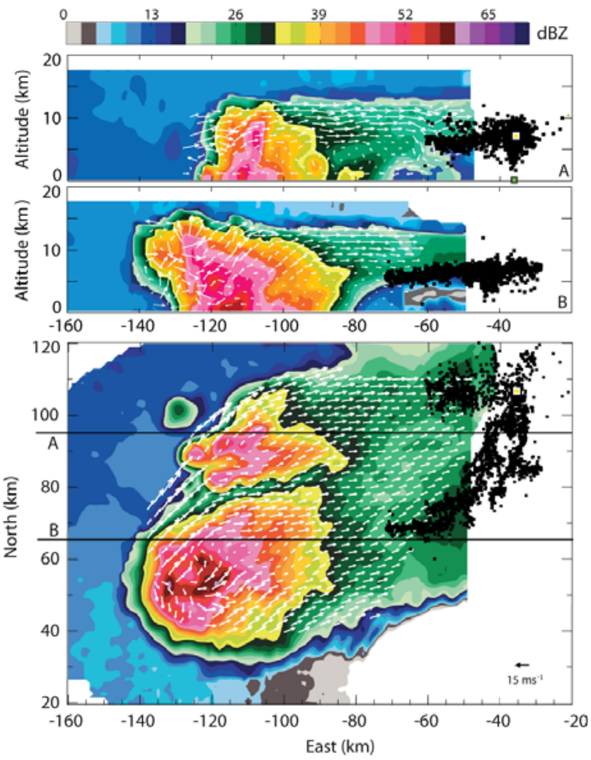

Fig. 4: VHF sources for a cloud-to-ground flash at 2321 UTC on 29 May 2004 superimposed on reflectivity and dual-Doppler winds (from Kuhlman et al. 2009). The location of flash initiation is indicated by a yellow square.